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Midlands Voices: Here's how pumping groundwater can lower a river

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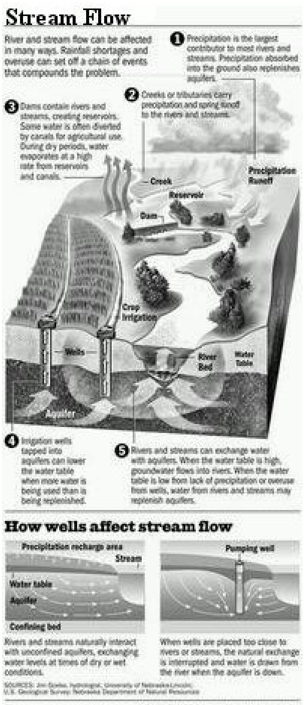

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Nebraska has reached a crossroads in the use of water, our most important natural resource.

In the last two decades, demands on water use have reached the limits of the supply in some of Nebraska's river basins. Disputes have arisen internally and with our neighboring states. Surface-water appropriators on the Republican River and Platte River systems have raised concerns that groundwater pumping has depleted their surface-water supplies.

In 1998, Kansas sued Nebraska, complaining that Nebraska's groundwater pumping was causing Nebraska to be out of compliance with the 1943 Republican River Compact. In 2000, the U.S. Supreme Court ruled that the compact regulates portions of groundwater use.

In 2001, litigation over the impact of groundwater pumping on surface-water supplies was initiated in regard to Pumpkin Creek, a Panhandle tributary of the North Platte River.

The common thread in each of these situations is the hydrologic connection between surface water and groundwater and how to manage this combined resource.

In response to these growing concerns, the Legislature formed a 49-member Water Policy Task Force. In 2004, the Legislature adopted the task force's recommendations and passed Legislative Bill 962.

LB 962 addressed the issue of managing hydrologically connected water supply and demand by amending the Groundwater Management and Protection Act to provide for proactive, integrated management of hydrologically connected surface and groundwater supplies.

Under Nebraska law, the local natural resources districts have been responsible for managing groundwater use. The Nebraska Department of Natural Resources has been responsible for administering surface-water supplies and ensuring the state's compliance with interstate compacts. LB 962 did not change this basic institutional structure.

LB 962 does require that the Department of Natural Resources and the NRDs work together to jointly develop and implement integrated management plans to manage hydrologically connected surface-water and groundwater supplies.

The key to developing a successful integrated management plan is an understanding of how the state's groundwater supplies interact with the state's surface-water supplies.

Unlike surface-water flow, which is relatively easy to understand because it is readily observed and easily measured, groundwater flow is hidden and difficult to measure. Groundwater moves much slower than surface water, often only a few feet per year.

This slow movement of water occurs through the pore spaces between the sands, gravels and other subsurface materials below the ground. These materials that store and transmit water are called aquifers.

To visualize an aquifer, think of a sandbox filled with sand. Now, pour water into the box. The water fills the empty spaces between the grains of sand. That is what happens with groundwater in an aquifer.

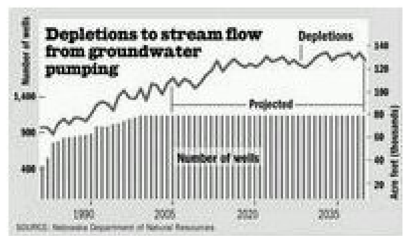
If there is a drain hole on the side of the sandbox, water will flow toward the hole until the sand is drained. The drain is like a river.

If you dig a hole in the sand in the middle of the box, you may see water in the hole. If you scoop water out of the hole with a cup, water will move into the hole from the surrounding sand. That hole is like a pumping well. Scooping water out of the hole in the sand reduces the amount available to go out the drain hole.

Water in Nebraska's streams comes from two sources: (1) runoff from local precipitation and, in some cases, Rocky Mountain snowmelt; and (2) discharge from groundwater aquifers.

While there are multiple aquifers in Nebraska, the High Plains Aquifer complex is the primary source of groundwater. This groundwater reservoir is mostly comprised of the Ogallala formation and overlying sands and gravels.

The Ogallala formation itself contains a complex mixture of sands, gravels, sandstones, silts and clays, much of which is well-suited for holding and moving groundwater. This formation was deposited over millions of years.



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In the natural state, water is removed from the groundwater system by evaporation, by consumption by plants and animals or by flowing out of the system to a stream. People also remove water from the integrated system, either by diverting it directly from a stream or by pumping it from wells (see graphic).

Much of what we know about groundwater movement comes from extensive geologic and climatological investigations over the last 100 years. In addition, we use groundwater models to further our understanding of the system and to make estimates of how much water might be available in the future under different management scenarios.

These groundwater models use available information such as groundwater levels, precipitation, pumping and stream flow to calculate water levels and flows everywhere in the aquifer. The model is constructed so that it matches all the real-world observations of the groundwater system.

How does water use affect the overall supply?

Though different in many respects, there are a number of basic principles common to both surface-water and groundwater systems.

- First, where groundwater aquifers are in hydrologic connection with surface-water streams, the two must be viewed as a single, integrated system. The addition of water to either the aquifer or the stream will result in an increase to the other over time. Likewise, the removal of water from either the aquifer or the stream will result in a decrease to the other over time. The integrated system constantly seeks a state of balance.

- Second, as a general rule, the amount of water entering any system over the long term must equal the amount leaving the system, including any change in the amount stored in the system. In the shorter term, if inflows exceed outflows, the excess is stored and the water levels in the aquifer rise. Conversely, if the outflow is greater than the inflow to the system, water levels in the aquifer decrease.

- Most importantly, there is not an unlimited supply of water in this system.

We all know that large portions of the state do not receive a lot of rain. In these areas, pumping may cause outflows from the integrated system to exceed the inflows to the point where streams dry up and wells go dry.

In other words, if pumping causes the outflow from the system to exceed the inflows, then other outflows such as stream flow, evapotranspiration (the use of water by plants, especially trees and shrubs in river valleys) and groundwater flow to other parts of the aquifer will be reduced until a new equilibrium is achieved.

In an integrated surface-water/groundwater system, depletions to stream flow can occur either by wells intercepting water that otherwise would have flowed to the stream or by causing water to move from the stream to the well.

The bottom part of the graphic diagrams a stream-aquifer relationship that is fairly typical of many of Nebraska's streams. If a well starts removing water from the aquifer, the well will intercept water that otherwise would have resulted in providing water to the stream.

As the well continues to pump, more water is removed from the system and less water reaches the stream. Eventually, if the pumping continues, water actually will flow from the stream toward the well.

Generally speaking, both surface-water diversions and groundwater pumping remove water from the system. But the short term impact of each on the stream can be dramatically different.

A surface-water diversion immediately depletes the stream by the total amount diverted. When the diversion is stopped, the depletion to the stream stops immediately.

When a well starts to pump, there is also an immediate depletion to the stream caused by the instantaneous dropping of water levels everywhere in the aquifer. But although the drop in the water table is substantially close to the well, the drop decreases away from the well until it is so tiny it cannot be observed.

Also in contrast to a surface-water diversion, after the well is turned off, depletions to the stream will continue to increase, often for many years, before they start to decrease.

For example, in a system like the Republican River Basin, a single well far from the river may not draw any significant amount of water from a river for 25 years and may take only 20 percent of its water from the river after 100 years. The well, however, will keep on taking water from the river hundreds of years after pumping stops.

This lag between the time water is pumped from the groundwater and the time the depletion is observed in streams is referred to as the "lag effect."

Some people assume that the lag effect is the result of the velocities at which water moves through the groundwater system; that is, if the groundwater velocity is 100 feet per year, it will take 50 years to see the impact on a stream of a well 5,000 feet from the stream.

This is not the case. An individual water molecule does not have to move from the stream to the well to cause an impact on the stream. Changes in water table elevation and aquifer pressure, not the velocity of water, determine when and how much a well will affect the stream.

To understand this concept, picture a person squeezing a toothpaste tube. If you squeeze at the bottom of the tube, toothpaste comes out the other end, even though the toothpaste hasn't moved through the entire length of the tube. Groundwater responds to changes in water table elevations and pressures in a similar fashion.

Because of the lag effect, a pumping well's impact on a stream will not be noticeable for some time after the well has started pumping, and it will be even longer before the entire impact of the well arrives at the stream.

For example, the chart depicts the modeled impacts of well pumping on a stream. The first part of the curve shows the increased amount of stream depletion caused as well development increases. After the year 2000, the number of pumping wells was held constant. Nevertheless, the stream depletion continues to increase until a new equilibrium is reached.

In reality, it is not easy to observe the impact of wells on stream flow. Often, variations in precipitation, pumping patterns and stream flow are such that only after many years can the impacts of pumping on stream flow be observed.

A long wet period lowers the demand for water, can partially refill available aquifer storage and mask the impacts of pumping. In contrast, dry periods, like the current drought, highlight the impacts of pumping.

In some cases, the impacts of pumping on groundwater tables are noticeable. But in others, changes in water-table elevation cannot be seen until stream flows have significantly declined.

Finally, not all the water diverted from a stream or pumped by a well is consumed and removed from the integrated surface-water/groundwater system.

Only the water that is actually consumed through evaporation or evapotranspiration is removed. The remaining portion of what was pumped returns to the system as surface-water runoff to a stream or as recharge to an aquifer. For this reason, what really matters is how much water is consumed.

For example, if the consumptive use of an acre of corn is 24 inches in a given year, 10 inches is supplied by local precipitation and the remaining 14 inches is supplied by pumping irrigation water. It doesn't matter significantly if 18 inches or 25 inches of water is pumped on to the field. In either case, only 14 inches will be consumed. The remaining 4 to 11 inches will return to the system as surface-water runoff or recharge to the aquifer.

To conserve water, it is the amount of water consumed, not just the amount of water pumped, that must be reduced.

Thus, unless the actual consumption of water is decreased, increasing the efficiency of an irrigation system will not automatically decrease the consumptive use of water.

Of course, increasing the efficiency of an irrigation application system has many other benefits, such as decreasing fuel and fertilizer input costs and protecting water quality.

In summary, under LB 962 where groundwater and surface water are hydrologically connected, the stream-aquifer system must be treated as one integrated resource. It is clear that if water is consumed, water will be removed from the system. There is no free lunch.

It is equally clear that the physical differences in how the use of hydrologically connected surface water and groundwater impact the system require different management techniques.

The management tools for both groundwater and surface water must, however, be coordinated to reach the common goals and objectives for the combined resource.
